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From the Editor . . .

The National Building Code of Canada was developed in the 1940s to promote uniformity in building standards across the country. It was developed as a model building code that could be adopted by local jurisdictions. The model code has been maintained and revised on a regular basis over the years.

The intent of the Building Code is to set out minimum provisions acceptable to maintain the safety of buildings, with specific regard to public health, fire protection, accessibility and structural sufficiency. It is not a textbook for building design.

From its inception, the National Building Code had a major unifying influence on building practices and building requirements across the country, although it has no legal status unless adopted by local authorities having jurisdiction.

The code development and management process involves staff and the Canadian Codes Centre as well as standing committees made up of volunteers from across Canada and all code user groups. Changes are made following considerable deliberation that includes public review. It is a system that has worked very well for many years.

Most provinces have adopted the model national code generally with minor changes to account for local and regional concerns.

We have recently noted a subtle but significant shift. We are seeing many provinces leapfrog each other to be the most energy efficient, the best or most advanced in class. to the point that the code uniformity is being lost.

Political whims and expediency seem to be driving changes behind the recent quick code changes. We are seeing this especially in relation to mandatory energy standards, fire protection and other social goals that are starting to drive the agenda, whether it is handicap accessibility issues, or environmental regulations.

Although the goals may be laudable, code changes need to be considered with care. Users may have a problem with the seemingly glacial pace at which code changes are implemented, and it can be frustrating, but the lengthy timeframe provides an opportunity for proper scrutiny and evaluation of all changes.

The danger is that divergent local codes make it difficult for industry and add unnecessary complexity and cost. Premature and arbitrary changes can actually imperil building durability due to unintended consequences of forced changes that have not been thought through. They can also imperil innovation due to overly prescriptive regulations that shut out viable alternative solutions. Some latitude is needed to permit innovation, and for market decisions to aid innovation.

Although I agree that regulations are often needed to push and prod the market – since there is a tendency to stay with the tried and true minimum standards – regulations need to be reasonable and facilitate innovation and improvement. At the end of the day the best regulations are meaningless if they cannot be implemented properly because neither regulators, designers nor builders can do what needs to be done. We already have seen such examples. Let's hope it's not a trend that is going to continue.

Richard Kadulski,
Editor

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Spray Foam 101

Spray foam insulation is increasingly being used in residential construction – anywhere that insulation is needed. Unlike other insulating products that are manufactured in a plant, brought on site, and installed, the spray foam chemicals are brought on site and. with the appropriate equipment, the product is manufactured as it is installed. A knowledgeable applicator is important for proper manufacture and installation of the material.

However, due to cost and availability issues, spray foam insulation often is used only for some details. Because the spray foam grows and adheres to all surfaces it comes in contact with, it is increasingly used to insulate and air-seal rim joist areas, especially when I-joists are used, because of the irregular profile of the joist.

Environmental considerations

Questions are often raised whether or not spray foam insulation is appropriate to use. There are concerns the product is not sufficiently environmentally responsible because it is largely produced from petrochemicals.

Although spray foam products rely on petrochemicals for the raw material, it is an appropriate use because the energy savings due to the use of the foam insulation will far outweigh the energy and resource cost of the raw materials. It is far preferable to take advantage of the petrochemicals for products with a long-term durable use, such as for insulation, than to use the product in a short-term use for vehicle fuel or some frivolous disposable product.

New chemical formulations are starting to use plant oils, and even some recycled content as feedstock, but in most cases the organic content is only a portion of the content.

What it's made of

Polyurethane, a chemical polymer, was first developed in the 1930s, and its use as spray foam insulation started in the 1960s. There are several spray foam products on the market. All are made by a chemical reaction that takes place between two chemicals, an isocyanate and a proprietary formulation with a blowing agent that generates the foam. The variations are based on chemical composition and type of blowing agent used. All are based on various polyurethane formulations.

The chemicals, in their raw form, are toxic and can be corrosive, but once they have been reacted, they form extremely durable products that are extremely tenacious – once they stick so a material, they are fixed permanently. That is why they make very effective air barriers.

Polyurethane is a chemically inert solid that is combustible and will ignite if exposed to an open flame for a sufficient period of time. It begins to breakdown at approximately 240 °C (464 °F).

The most commonly used spray foam products used in construction can be classified as open celled half-pound foams, and closed cell two-pound foam.

Open Cell (Half-pound) Foam

This is a light-density foam material, referred to as half-pound foam. Depending on the manufacturer it has an average R-value of about 3.6 to 3.8 per inch thickness. With a higher density than fibrous insulation materials, it provides an effective insulation that is also airtight – enhancing, or forming a major portion of a building's air barrier system.

When installed, it is a semi-flexible material resembling a soft sponge. Although it is airtight, it has a relatively high rate of vapour transmission, so a vapour barrier, in the form of low permeance paint on the interior surface of the foam or drywall, or an equivalent low permeance product, is required. Liquid moisture

Open cell spray foam being installed in wall.

will travel directly through the material.

Open cell foam has a very high expansion ratio, and can be applied to any thickness desired in a single pass application. For walls, cold floors or vaulted ceilings, where the full framing cavity is insulated, the spray foam is trimmed back after application to provide a flush surface for the interior finishes.

Most open cell foam products are not affected by temperature at time of installation, so they can be installed when temperatures are below freezing.

Closed Cell (Two-pound) Foam

Closed cell foam has a higher density that, when installed, is hard and resembles extruded polystyrene. It has an average R-value of about 6 per inch thickness. Original blowing agents produced high R-values, but also relied on ozone depleting gases. The use of these is being phased out, so that the overall R-value is decreasing slightly. Depending on the foam manufacturer, and the blowing agents used, the R-value can be a bit less or a bit more than 6 per inch thickness.

Application Safety considerations

Medium density (two-pound) polyurethane is created by an exothermic chemical reaction – meaning it gives off a lot of heat when it is foamed, so it can only be applied in 2" thick passes to allow cooling. A second pass can be applied several hours after the first pass, but in no case can more than 4 inches of spray foam be applied in a day. Where thicker insulation is desired, it must be applied on a following day.

The heat generated can be enough to cause a fire and there have been instances where fires have been caused because of improper installation. One of the requirements of the ULC standard governing polyurethane spray foam is that applicators must have a fire extinguisher on site when they are spraying 2-pound foam.

Closed cell polyurethane foam cannot be installed when temperatures are below freezing.

The half-pound (open cell) spray foam has a different chemical reaction, and a much higher rate of expansion so the same limitations on thickness of application do not apply.

Insulation performance

Polyurethane is extremely tenacious and can also be used as a moisture barrier. It adheres to all surfaces it comes in contact with. A National Research Council research study of basement insulation and moisture proofing details found that the sprayed in-place polyurethane insulation outperformed other insulation options. Because polyurethane was so tenacious, they were not able to fully remove all the polyurethane for post-test evaluation.

Polyurethane has a low permeability – a 2-inch thickness has a permeability of 60 ng/Pa·s·m^2 which qualifies it as a vapour barrier. The permeability decreases with thickness.

CAN/ULC-S705.1-01 (*Standard for Thermal Insulation – Spray Applied Rigid Polyurethane Foam, Medium Density Material*) is the product standard that applies to closed cell polyurethane, and is referenced in the building code.

Because of the layering of the spray foam, the spray foam layers increase the foam's overall thermal value higher than normally associated with standardized thickness values (i.e., x R-value per inch). CAN/ULC-S770 (*Standard Method of Test for Determination of Long Term Thermal Resistance of Closed-Cell Thermal Insulating Foams*) sets out the measurement approach for thermal value, and identifies this as the Long Term Thermal Rating (LTTR). Thus some manufacturers will also provide this value with their product literature. That is why 4 or 4 ¼" of closed cell foam can provide an R-value of 28, although the nominal R-value for the product may be 6 per inch thickness.

At this time, there are no comparable ULC standards for the open cell (half-pound) foam products.

Code Issues

Spray Foam in Walls

Two-pound polyurethane insulation is referenced in the building code, so generally there are no problems associated with its use. However, we've noted that building officials are not always familiar with product, and the fact that closed cell foam can be both the air barrier and vapour barrier.

Recently, we've encountered a situation where two-pound foam insulation was used to provide R-20 wall insulation and the building inspector insisted on the installation of polyethylene overtop. He doesn't understand that the spray foam can create as effective an air barrier as a conventional polyethylene application (if not more so). The polyethylene is not only redundant, but could be detrimental to the durability of the house, because the permeability of the combined polyethylene and polyurethane foam could completely block any water vapour diffusion through the assembly, removing any potential drying through the assembly.

One of the reasons building officials have difficulty with two-pound spray foam as an air and vapour barrier is because it has only recently been identified that wood framing has a low permeability, and by itself qualifies as a vapour barrier.

In the case of half-pound foam, the situation is a bit different, because while the foam can be the air barrier, there is still a need for vapour diffusion resistance. However, even with this product, a better solution would be a slightly more permeable vapour barrier than polyethylene.

Spray Foam Insulation in Ceilings

Spray foam insulation, both half-pound and two-pound foam, is increasingly used in unvented roof applications (also referred to as hot roofs) throughout North America, and can be shown to comply with the intent of the Building Code.

The intent of ventilation requirements in the building code is to minimize condensation that may occur on the underside of the roof sheathing because of any moisture driven by air leakage. Roof ventilation above the insulation in a leaky ceiling assembly can draw warm moist air from the interior through air leakage in the building envelope thus contributing to moisture problems.

Air leakage has been identified as the principal carrier of moisture that can lead to deterioration. This is acknowledged in the Appendix notes to the code (A 9.19.1.1 (1)) that states "*controlling the flow of moisture by air leakage and vapour diffusion into attic or roof spaces is necessary to limit moisture-induced deterioration. Given that imperfections normally exist in the vapour barriers and air barrier systems, recent research indicates that venting of attic or roof spaces is generally still required. The exception provided in article 9.19.1.1 recognizes that some specialized ceiling-roof assemblies such as those used in some factory built buildings, have, over time, demonstrated that their construction is sufficiently tight to prevent excessive moisture accumulation. In these cases, ventilation would not be required.*"

The airtightness provided by the spray foam insulation prevents the dissipation of water and moisture by preventing its entry into the structure, because it prevents moist interior air from seeing cold surfaces that would allow condensation leading to structural deterioration. Thus an unvented roof deck assembly, insulated with

Open cell spray foam insulation in attic renovation. Spray foam insulation applied directly to roof sheathing, for full rafter depth, in an un-vented roof detail. Area above collar ties remains as attic space, but because it is insulated and the insulation is the air barrier, it is all interior space. The foam insulation has been painted with vapour barrier paint.

spray-in-place foam insulation, meets the code objective to limit the probability of structural failure caused by damage to or deterioration of building elements by eliminating air leakage out of the heated envelope.

Foam insulation products are recognized as effective at providing a continuous, effective air barrier as well as insulation. The nature of the product (an expanding foam) ensures an inherently airtight assembly that can fill all voids not otherwise accessible with conventional batt insulation products. Because air movement is blocked through the material itself, moisture cannot get into the roof structure, and the structure itself will be free from moisture problems.

Functionally, the spray foam insulation applied directly against the interior side of the roof and wall sheathing is the same as structurally insulated (or stressed skin) panels that have been and are being used successfully in thousands of buildings throughout North America. ☼

Spray Foam Application At Pot Lights

There is a requirement for proper clearances of spray foam at pot light housings, even if they are IC units. The minimum is 3" on all sides of the pot light to spray foam. These clearances are specified in all spray foam manufacturer's product literature, and are a safety issue.

Rigid insulation should be used behind the pot light against the wood deck (it should be tight against the roof deck). There must be a minimum gap – no less than ½" between the top of the IC pot light and the rigid foam. The rigid foam behind the pot light housing should be iso-board (which has a higher temperature threshold).

The spray foam insulation on the roof should then be sprayed to 'lock-in' the iso-board, and form a continuous air barrier.

Light efficiency

Lighting output is measured in terms of lumens.

An incandescent lamp generates about 14 to 17 lumens per watt.

Fluorescent tubes average 50 to 67 lumens/watt.

Most compact fluorescents rated at 13 W or more with integral electronic ballasts achieve about 60 lumens/watt

LEDs currently on the market average 100 lumens/watt or more. Luminous efficiencies as much as 200 lumens/watt are possible.

LED: Light emitting diodes

We are seeing the start of a new revolution in lighting. When Edison developed the electric lamp at the end of the 19th century, it had a big effect on people's lives. Before that, most work and play took place during daylight hours. With the development of electrical lighting and electrical grids, life took on a new pace because no longer was there a reliance on the position of the sun. Any type of activity could take place any time of the day or night.

Early electrical lighting relied on incandescent bulbs. The traditional incandescent light bulb creates light when an electric current runs through a filament and heats it to a high temperature so that it glows and produces visible light. However, it is very inefficient –more than 95% of the energy is emitted as heat – which is why lighting is an important part of a building's energy balance. As well, incandescent lamps have relatively short life spans, typically about 1,000 hours.

Incandescent bulbs will soon disappear completely around the world by regulation. A more efficient lighting technology developed in the 20th century was the fluorescent lamp. This produces light when electricity passes through mercury vapour to produce ultraviolet light, which is then absorbed by a phosphor coating inside the lamp, causing it to glow, or fluoresce. The heat generated by a fluorescent lamp is much less than in an incandescent lamp. Fluorescent lamps have longer life, typically 10-20,000 hours. Compact fluorescents are now increasingly becoming a replacement for the older incandescent lamp.

A new light source, the light emitting diode (LED) has captured the imagination of many. It is expected that LED lighting will reduce the need for electricity in lighting by up to 80%. They are already used in specialty applications, for example, signs and decorative lights including Christmas tree lights.

Anyone that has travelled or seen pictures of redeveloped eastern cities cannot fail to be impressed by the glitter and lights. Brightly lit cities like Shanghai – colourful with incredible light show displays – rely on LED lighting.

It is expected that in the future, LED, rather than fluorescent lighting, will be the norm in the home environment, replacing the traditional incandescent bulb. The electrical energy consumption in the coloured illuminated signs can be ninety-five per cent less compared with those lit by the traditional fluorescent tube. However, much work remains to be done.

The LED lamp is a solid-state lamp that uses light-emitting diodes as the source of light. It has a lifespan of 30,000 hours, and unlike fluorescent lamps, does not dim over time. Because the light output of individual light-emitting diodes is still small compared to incandescent and compact fluorescent lamps, multiple diodes are bundled together. Currently, the brightest bulbs offer the equivalent of a 45-60 watt incandescent bulb, and most cannot be dimmed. As well, there is still a significant amount of heat absorption by the diodes. Further development is expected to bring about improvements in the light characteristics, lighting level efficiency, as well as cost reductions.

Human perception of lighting by LED depends to a great extent on the type of LED used and its colour temperature – blue, yellow or red hues, colour rendition, good (up to CRI = 100) or poor (CRI below 70). A yellow or red hue with good colour rendition is perceived favourably. Research is continuing concerning human perception of light from light emitting diodes.

The semiconductor material from which LEDs are made is produced in large wafers, which are divided into small pieces, each of which gives rise to a light emitting diode. Each wafer can be made into thousands of LEDs of varying quality and hue.

Further development will have to produce several diodes of high quality and the same hue from the same wafer. At present, "white light" is produced from fluorescent coatings (similar to conventional fluorescent tubes), which at the same time produces a certain quantity of blue light from the diode.

It is expected that within thirty to forty years LEDs will be the dominant lighting technology. They will provide the same amount of light as that produced at present, with only ten per cent of the present energy use. Around the world this will provide enormous environmental benefits, by reducing electrical loads. These load reductions are not only for reductions in lighting power, but also for air conditioning loads, because of the reductions in heat generated by lighting. ☼

Passivhaus

There are many ways to define energy efficient construction. Many programs that set out the benchmark for low energy construction have emerged over the years. Canadian builders know about the R-2000 program, which was one of the earliest and most robust standards in the world.

Over the years, improvements have been made to mechanical system equipment, new products have been developed, and builders have become more comfortable building high performance houses. What was perceived to be aggressive some years ago seems almost commonplace today. In some jurisdictions, steps to improve construction standards in response to the need to address climate change mean that regulations are approaching the performance requirements of the original R-2000 standard.

The R-2000 standard is a voluntary initiative that sets out standards for energy efficiency in buildings and addresses indoor air quality.

Over the years, in other parts of the world, others have also been working on low energy home standards. Many of these learn and borrow from each other. One of these is the Passivhaus standard developed in Germany. Borrowing from and building on Canadian and Scandinavian housing research, several ultra-low energy homes were built in Darmstadt, Germany in 1990.

These low energy homes became the impetus for the creation of the Passivhaus-Institut in 1996, which was founded to promote and control the Passivhaus standard. Since then, an estimated 15,000 Passive Houses have been built – mostly in Germany and Austria –

although there has been interest in Canada and the US, where an American group has established the US Passive House Institute, and passive homes have also been built in other European Union countries. The first certified US Passivhaus was built in Minnesota in 2006.

A Passive House is a very well-insulated, air-tight building with minimized heat losses. It is primarily heated by passive solar gain and by internal gains from people, lights and appliances. Heat that may be needed is provided by a small heater. Careful design to avoid heat gain through shading and window orientation helps to limit cooling loads. A heat recovery ventilator provides a constant, balanced fresh air supply. The result is a system that not only saves on space heating costs, but also maintains good indoor air quality.

Like the R-2000 standard, the Passivhaus is a holistic, systems-based approach to designing very low energy buildings. The Passivhaus criteria are meant to result in dramatic energy reduction of around 80% compared to the energy consumption of typical existing German buildings.

Key Passivhaus criteria include:

- ☞High levels of thermal insulation with attention to thermal bridging across the building enclosure.
- ☞High efficiency triple or quad-glazed windows: (U-values of 0.7-0.85W/m^2.K)
- ☞Heat recovery ventilation
- ☞Simple but innovative heating system

Performance requirements:

- ☞Heating energy less than 15 kWh/m^2 per year
- ☞Air tightness: not more than 0.6 air changes at 50 Pascals
- ☞Total primary energy consumption (primary energy for heating, hot water and electricity) less than 120 kWh/m^2 per year.

The original R-2000 energy budget was 55 kWh/m^2 per year. Homes built to this standard would consume almost 70% less energy than pre-1975 Canadian housing. With the improvement in construction practices, and incorporation of minimum energy standards into codes, that gap has narrowed considerably. Currently, the R-2000 standard is being revised and will become significantly more aggressive. Although not finalized yet, the working assumptions are that the energy consumption targets will be about 50% lower than the current targets.

Measurements of energy consumption, to be comparable, must take into account how the calculations are done and what is included. Canadian floor area calculations are not done exactly the same way as in Europe. While there are similarities, they are not identical.

Passive House Design & Construction Checklist

What does it take to build a Passive House? We've adapted this checklist from the Passive House Institute UK web site. Some of the items listed in Europe are standard practice in Canadian construction. However, other points provide a good review of points that need to be considered when designing and building any energy-efficient home – it could be equally applied to an R-2000, Built-Green or Energy Star Home.

A major part of achieving a low energy home is paying attention to the quality control process during the design and construction process.

Site planning

- Is the site suitable for a Passive House?
- Is a southerly orientation (±30°) and large south-facing window areas possible?
- Is a compact building shape possible?
- Are there any shading factors that may prevent the use of solar gains? In urban areas, it could be tree retention bylaws.

Home design

- South-facing glazing permits solar gains. East, north, and west facing glazing should be big enough for light, but not larger than necessary.
- Minimise winter shading by landscaping, outbuildings, house features, including roof overhangs.
- Simple house shape – avoiding jogs in walls, dormer windows, will make it easier to build the air barrier.
- Floor plans that concentrate service areas simplify plumbing and mechanical runs.

Construction plans

- Review wall/foundation/roof construction and insulation details.
- Address thermal bridging details – modify as required, minimising thermal bridges wherever possible.
- Allow enough space for mechanical systems. Make sure there is enough space and access for regular maintenance.
- Well-insulated construction assembly details – according to Passive House rules, for the external enclosure the overall U-value should be 0.15 W/(m^{2}K) (an effective R-value of about 38).
- Review airtightness construction details.
- Optimise glazing: type of glazing and frame materials for the location and orientation
- Glazing U-value should not exceed 0.8 /(m^{2}K) (an effective R-value of about 7.2 – or quad glazing).
- Calculate the space heating demand using appropriate software.

Heating and ventilation ducts

Ventilation system layout:

- Keep cold ducts outside the heated envelope. If they need to be inside they should be as short as possible, well-insulated and with a sealed vapour barrier.
- Keep warm ducts inside the heated envelope. If they need to be outside then only for very short lengths and they should be well insulated
- Keep duct runs as short as possible.
- Design measurement and flow balancing facilities into the system
- Place the heat recovery ventilator (HRV) close to the exterior to minimize cold duct runs
- The HRV should have an overall efficiency of 75% or better and a low power consumption
- The HRV should have high, normal, low speed controls
- Kitchen range hoods should have good exhaust capacity at a low flow rate and be vented to the exterior.

Plumbing

- Keep plumbing runs as short as possible
- Insulate hot water lines
- Use low flow toilets, faucet aerators
- Use drain water heat recovery
- Use energy efficient appliances.

Construction phase

- Site management: Check that all materials supplied actually correspond to the materials specifications. Run a clean site with minimal waste.
- Reducing thermal bridges requires on-site quality control.
- Maintain integrity of the insulation, to ensure there are no gaps or voids in the insulation.
- Airtightness: Check transitions between elements and materials e.g. between walls and floors, seals at penetrations through the air barrier for pipes, cables or flues while still

accessible. Do a preliminary fan door test as early in the construction phase as possible.

- Check air tightness of ducts for ventilation and heating system.
- Mechanical equipment: check accessibility for servicing, filter change and noise reduction measures
- Check duct insulation - is it present where it is needed and installed correctly?
- Measure intake and exhaust airflows for the ventilation and heating system to ensure they are balanced and at appropriate levels.

Post Construction

- Unless the owners and tenants understand their building, they will not automatically operate or maintain it appropriately. That is why a user manual is important. It can be simple binder with user instructions, technical manuals for installed equipment, warranties and contact details for service and maintenance functions

Certification

- A third-party reviewed certificate verifying compliance with a standard is, in the end, the only way to be certain that the house is what it is supposed to be.

Letter to the Editor

Re Wall Energy Ratings, Solplan Review 151, April 2010.

I have a question regarding the statement that the half-pound foam in most cases outperformed the two-pound foam. I was hoping the article would express an opinion why that may be the case, although I realise the article was focusing on the difference between spray foam and conventional batt insulations.

I am a custom builder in Fort St. John. We have been using Roxul mineral wool insulation instead of fibreglass in our walls and blown cellulose in the attics for several years now. The home we are currently building will have 4½ inches of 2-pound foam in the outside walls because it gives us the R-22 we need for the wall as well as providing the vapour barrier we need. We are also going to use 2 inches of closed cell foam sprayed down on the drywall ceiling, with the balance blown insulation to meet the insulation.

I am considering changing to 2x4 framing with 2-pound polyurethane spray foam insulation and adding polystyrene on the exterior to address the thermal bridging issue.

I am curious to hear your comments on my ramblings, and especially on why the half-pound foam would outperform the two-pound foam. My spray foam installer uses 2-pound Polarfoam PF-7300 that has an aged R-value of 6 per inch thickness and a published air permeability of 0.00004 L/s-m^2. The half-pound foam he uses is Icynene LD-50 with an aged R-value of 3.8 per inch and a published air permeability of 0.0049 L/s-m^2.

Matthew Carpenter
Montney, BC

You ask a good question – one that the researchers will say is worthy of further research.

It is important to remember that the wall air barrier requirements defined by CCMC are set at 0.05 l/(m^2.s) at $\Delta P = 75$ Pa. Products generally list their properties as tested in a laboratory – in isolation. That is how Icynene and Polarfoam would have established the air permeability values they quote.

The NRC testing, although still a laboratory test, used mocked-up walls with penetrations, such as a duct, electric boxes and wiring, and a window, so that the air tightness was measured for a whole system, and not just a single material.

The construction assembly you are considering – 2-pound polyurethane insulation between studs, with 2 inches of extruded polystyrene insulation across the sheathing -- is a very good system, especially since that gives you a very efficient way of addressing not only thermal bridging but also air sealing.

In the future, you will see energy codes requiring construction details that provide higher effective insulation requirements. This will mean the use of rigid insulation across the exterior sheathing will become the norm.

(See Spray Foam 101, p. 3)

Window R-values

Insulation is measured by the R-value, which is a measure of the product's resistance to heat transfer. It is the ratio of the temperature difference across the material and the heat flow. The more heat flow that is slowed or retarded, the better the insulation of the material, and the higher the R-value of the material.

The R-value is measured under specified test conditions in a laboratory. These are the nominal R-values provided by the manufacturer, and used most commonly by designers and builders. Effective R-values are the actual thermal resistances provided by the insulation in an assembly, and can be much lower than the nominal R-value of the insulation materials due to thermal bridging through all the construction materials.

Although insulation materials are typically referred to by R-value, construction assemblies can also be identified by thermal conductivity, known as U-value. The thermal conductivity of a material indicates its ability to conduct heat.

There is a direct relationship between the two: U=1/R (or R=1/U). Thus, the bigger the R-value, the better the insulation. The smaller the U-value, the better the assembly.

Although insulation materials are measured and identified by their thermal resistance value (R-value), windows are generally identified by their thermal conductivity, or U-value. Code standards typically refer to U-values even when insulation levels are referred to by R-value.

In the commercial construction sector, and in other parts of the world, building enclosure thermal properties are often referred to by their U-value, rather than R-values. A reference to overall U-values captures the rate effective for the total building enclosure, rather than just for discrete construction elements, as is the standard approach used for houses.

The conversion between U- and R-values for typical glazing values is shown in the tables.

U-value (W/m^{2}K)	R-value (ft^2·°F·h/Btu)
3.1	1.86
2.5	2.3
2	2.88
1.6	3.6
1.4	4.11
1.2	5.76
.5	11.52

U-value (W/m^{2}K)	R-value (ft^2·°F·h/Btu)	Typical window characteristics
5.7	1	Single pane window
2.8	2	Clear double glazed (no low-e or argon)
2	2.88	Double glazed, low-e, argon, wood or vinyl frame
1.4	4.11	Triple glazed, 2 low-e coatings, argon.
1.2	5.7	Triple glazed, 2 low-e coatings, argon, insulated spacers, high performance frames.

Window characteristics only indicate typical configurations – specific window and frame designs could have different values.

U-value is measured in watts per kelvin per metre (W/ m^2·K) per unit thickness.

R-value is square-metre kelvins per watt (m^2·K/W). In imperial measure, it is ft^2·°F·h/Btu.

Energy Savings With Smart Windows

Changes in window technology and control strategies can be used to control light and energy performance through windows. A graduate student at Uppsala University in Sweden has been developing a program to simulate energy flows through windows. This will allow the development of control strategies based on daylight needs when the premises are occupied, and on energy needs when the building is unoccupied.

Although this sounds like a little bit of science fiction, there already are smart glazing products used in specialized applications that change their light transmission based on light levels. New products and controls may also do the same with energy flows.

This may pave the way to new ways of looking at window performance. It may first be of special interest and benefit to larger commercial and institutional buildings, but could also apply to homes, especially some high-end homes with large glazing areas.

Canadian Home Builders' Association

Technical Research Committee News

CSA Window Installer Certification Program

CSA continues to move forward with the development of a personnel certification program for window, door and skylight technicians. This national certification program, the Fenestration Installation Technician Program (FIT), is being developed in partnership with the Canadian Window & Door Manufacturer's Association (CWDMA) and NRCan's Office of Energy Efficiency. It is intended to meet industry's needs for consistent, quality installations based on Canadian Windows and Door Standards (CSA-A440 Series, A440.4, A440.2) and best practices, and to improve consumer confidence.

A committee representing the interests of manufacturers, contractors, consulting engineers, tradespersons, educators and consumer representatives from across the country has been selected to oversee the certification scheme. It is expected that the certification will be operational by the end of 2010 or early 2011. Program details are still being worked out.

Effectiveness of Fire Sprinklers in Single Family Homes

There has been a strong drive for some time now to require mandatory sprinklers in all residential construction. The City of Vancouver was a jurisdiction that mandated them many years ago. However, there are still many questions about just how cost effective they really are.

Proponents focus on the emotional side of the consequences of fire, and often make optimistic claims about the cost and benefits. Regrettably, there have been few carefully documented studies that have been done to determine just what the costs of sprinklers are and how they perform, compared to the situation in communities that do not impose mandatory sprinklers.

A study being finalized has undertaken a statistical analysis of fire incidences in a number of communities in Canada and the US – they are looking at locations where fire sprinklers have been mandated for some time, and comparing them to similar communities nearby without mandated sprinkler requirements. The study is looking at impacts on property damage, personal injury, deaths and cost impacts, and cost per life saved.

This study should go a long way to answer key questions about fire sprinkler effectiveness and cost. It is hoped that the study will be completed early this summer.

Health Canada Radon Program

Canadian radon guidelines have been updated and have become more stringent as a result of a better understanding of the concerns. Coming building code changes will require homes to be built to facilitate radon remediation should it be determined to be necessary. This will also require builders, renovators and other home support professionals to understand what to do.

Health Canada is working on developing a Canadian certification program for radon professionals. It will build on the lessons learned from the US experience and US training and certification programs. For example, in the US much radon testing is done for real estate transactions, so two-day tests are permitted. However, a short one or two-day radon test is simply not appropriate, as it can provide incorrect results. Testing to determine radon concentrations must be done over a longer term, and during the winter.

The Canadian certification program will include ongoing quality assurance protocols and reviews of radon professionals as well as testing laboratories.

A radon testing program for federal buildings is underway. To date, more than 2300 buildings have been tested. They have found that about 9% of buildings tested have radon levels higher than the 200 Bq/m^3 acceptable level. Most of these are smaller one- and two-storey house type buildings. No evidence of radon has been noted in high-rise buildings.

Another two-year testing project is looking at 18,000 homes across Canada – this will be a three-month test during the winter. The results from the first batch of homes in year one of the study are being analyzed. Initial results show that radon is being found in areas previously known as radon rich, and also in other areas not previously surveyed.

A Radon mitigation guide is to be published in August this year. It will be an electronic document available on the Health Canada web site. As well, an education and awareness campaign will be undertaken later this year, and will rely on outreach through non-governmental agencies, health professionals, retailers, as well as the Internet and conferences and workshops.

EnerGuide Rating System

The EnerGuide rating shows a standard measure of a home's energy performance. The rating is calculated based on standard operation assumptions so that the energy performance of one house can be compared against another.

The EnerGuide rating has been the assessment tool for the ecoEnergy and EnerGuide retrofit incentive programs and also various local and regional energy efficiency programs. Since its inception, well over 635,000 existing homes have been evaluated. In addition, more than 25,000 new homes have been rated.

The current EnerGuide scale rates a home's energy efficiency level on a scale of 0 to 100, where a rating of 0 represents a home with major air leakage, no insulation and extremely high-energy consumption. A rating of 100 represents a house that is airtight, well insulated, sufficiently ventilated and requires no purchased energy on an annual basis.

With the move to increase energy efficiency standards, a number of provinces are moving to require a minimum EnerGuide 80 rating. However, the rating was not designed as a regulatory tool. That is why NRCan has initiated a revision process for the rating system. They are following a Standards Council of Canada process for codes and standard development, and have initiated a stakeholder review.

Preliminary indications are that the scale is going to be changed. What is being discussed is not a revised scale of 0 to 100 but rather an EnerGuide label which will provide the energy consumption for the house, with some descriptive information about the house characteristics. Thus, two different sized houses with an 80 rating under today's scale could have different numbers with the new scale because of the inherently greater energy consumption of the larger house. In this way, it should be clear that a small energy efficient house could use less energy than a large house.

Energy Star Labelling

Many products can be labeled as being Energy Star. However, because the Energy Star label is used internationally, it is important to recognise that not all products qualify as Energy Star in all markets. Insulation and air sealing products are NOT included in Canada's Energy Star program.

Natural Resources Canada (NRCan) works closely with the US EPA to harmonize product specifications and promote consistency between the Energy Star programs between Canada and the United States. However, there are differences in program approaches, so that occasionally there will be differences between the types of products and activities supported by the program in the two countries. In Canada, the Energy Star Program focuses strictly on a product-based qualification system only.

With respect to insulation, the position of Canada's Energy Star program is that installed R-values are more important than the rating on the products themselves. The effectiveness of insulation depends on the quantity and quality of the installation.

Insulation and air sealing initiatives are being promoted through the ecoENERGY program, and grants have been provided based on the insulation levels achieved, as well as installation verification by a certified energy adviser through a pre- and post-retrofit home evaluation.

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.

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You asked us: About ventilation and indoor air quality

How long does a heat recovery ventilator (HRV) need to run to maintain reasonable air quality and humidity control? Is there a recommended amount of time until the entire volume of air in a house is replaced?

We live in a cold northern climate, where a continuous airflow, even at low speed, in a continuously running HRV causes homeowner frustration with high heating bills. And even the most efficient HRV must still use electric heat to warm up the exchanged air when the outside temperature is -40 °C.

You ask a very good question, and one that that does not have a simple answer. The ventilation system is intended to exhaust stale contaminated air and provide fresh air to maintain good indoor air quality for the occupants. At the same time, the air change will be providing humidity control. In cold climates, and during cold weather, the outdoor air is so dry that it provides a significant amount of dehumidification.

We do not breathe intermittently, but rather need a continuous supply of air. Of course, the volume of air in a house represents a large reservoir, so if we don't ventilate for a period of time, it will not necessarily mean toxic conditions, even though it may not be fresh in the house.

Ventilation codes and standards have set their criteria based on studies that have shown that the average person needs about 7 cubic feet of air per minute. This has then been translated into various formulas, based on total room counts, or number of bedrooms, or as a proportion of total house volume, along with assumed airtightness of houses.

No house is perfectly air sealed, so the air change will always be a combination of air change through the ventilation system, and passive air leakage. The passive air leakage does not guarantee good air quality, since you really don't know where the leakage paths exist, and will be at their maximum during the coldest weather.

The real solution, assuming the house is airtight, is to make sure the HRV system is correctly sized, balanced, and has an appropriate control strategy. If the house is not airtight, then there is little benefit to be had from the HRV.

If the house is unoccupied for prolonged periods, or is particularly large with a very small occupancy, it might make sense to look at some form of automatic intermittent control, that otherwise allows for continuing air change. If the house is very small, with a large occupancy, the ventilation air needs will be somewhat larger, and no matter what, it may not make sense to cut back on ventilation.

What must be recognized is that ventilation air change will always have an associated cost – it doesn't matter whether the air comes through the HRV or through passive airflow. It's just that the HRV introduces the fresh air at a known, controlled rate, with a measure of heat recovery. In extremely cold climates, that may mean supplementary preheating of the incoming air so that there are no perceived drafts. HRVs can work effectively and comfortably, even in the harshest of climates, but the system must be properly designed and installed.

"Natural" air leakage provides air change, without any heat recovery, without controls, and provides maximum air change during the coldest times of the year and little during the shoulder seasons (spring and fall). Natural air change also adds costs to heating bills – probably more than the HRV.

Perhaps what needs to be developed is a control strategy that will moderate the air flow rate based on incoming air temperature, so that during the coldest period, when there may be enough air change forced passively by stack action flows, the HRV supply becomes a trickle.

I've experienced that even in balmy Vancouver ventilation air introduced into a radiant heated living space can create some discomfort in the winter. Although the incoming air is preheated by the HRV, the incoming air that is directly distributed can remain a few degrees cooler. People that are especially sensitive to air movements can feel the cooler air and be discomfited by it.

In homes with a forced warm air heating system where the furnace fan and ducts are used to distribute the incoming air, there will be mixing that takes place so the fresh incoming will be mixed with the house air, thus reducing the apparent drafts. ☼

Water Efficient Toilets

Ontario has announced a proposed ban on the sale of new toilets that use more than six litres of water. The province hopes to quell Ontarians' voracious demand for freshwater – at 260 litres per capita, nearly double that of European countries with similar living standards.

Unbeknown to most Canadians, an Ontario company has already created one of the world's most efficient toilets. Hennessy & Hinchcliffe Inc. of Mississauga, launched the Proficiency Ultra High Efficiency Toilet (UHET) last year. The Proficiency toilet flushes both liquid and solid waste effectively with one three-litre flush.

The market may be heading towards greener choices for the obvious environmental benefits, but what still concerns many homeowners is a toilet's ability to flush waste on the first push of the lever. The secret of this innovative Canadian technology is a patented air transfer system that pressurizes and depressurizes the toilet's trapway with the displacement of air as water fills and empties the tank.

The Proficiency toilet's performance has been tested by Veritec Consulting of Mississauga, which is one of the primary testing labs for all toilet manufacturers in North America. When their testing program was first established in 2003, half the toilets tested failed to meet then current minimum performance criteria.

The water and dollar savings potential is huge because these ultra low flush toilets use 37% less water than current low flush toilets. This could save homeowners hundreds of dollars a year, and municipalities millions in reduced costs to pump, distribute, and treat water and wastewater.

Sidewall Venting Of Gas Appliances

Traditionally, combustion appliances have been vented through the roof. The buoyancy effects of warm gases quickly disperse them upwards into the atmosphere through the chimney or venting, where there are no consequences.

High efficiency gas units have lower temperature flue gases, so gas codes have changed, permitting the venting of combustion gases through the sidewall of the building. This is increasingly being used to save time, materials and labour and interior living space in both new construction and renovations.

However, sidewall venting can have unintended consequences on the performance and durability of the building, and could lead to widespread problems affecting the building envelope unless the potential impact of sidewall venting is recognized and addressed.

This is an example of a heritage building in Ottawa that is suffering because of the high efficiency gas fired heating equipment that was installed. Condensation is visible on an adjacent wall, well removed from the vent. It will certainly affect the durability of the building.

Energy Answers

Rob Dumont

Will site-generated photovoltaic energy ever be price competitive with grid electricity in Canada?

The trend in pricing is encouraging, with declining prices for PV and increasing prices for grid-based electricity, particularly in those provinces (Alberta, Saskatchewan, Ontario, and Nova Scotia) where a large part of the electricity is generated by fossil fuels, primarily coal.

In my province of Saskatchewan, the utility is predicting a doubling in the retail price of electricity over the next decade from the current price of about $0.11 per kilowatt hour.

The cost of photovoltaic generated energy, however, continues to decline. Prices are being tracked by a web site called Solarbuzz.com.

As of May 2010, the Solarbuzz web site says that in the United States, residential PV has a cost of $0.35 US per kWh and industrial PV has a price of $0.19 per kWh. Back in 2000, the residential price of PV was $0.40 per kWh. There are not many commodities that are cheaper now than 10 years ago. PV is an exception.

One of the encouraging trends with PV systems is a rule of thumb used in manufacturing. Every time that you double the volume of production of a product, you can reduce the unit cost by about 10%.

According to the Wikipedia web site, the worldwide volume of production of PV has been increasing by 48% a year since 2002. As of 2008, the worldwide cumulative installations of PV were 15,200 megawatts.

The current world use of all forms of electricity is 15 Terawatts, or 15,000,000 megawatts. With the current PV installations at about 15, 200 megawatts, PV still provides far less than 0.1% of the world's electricity supply. The potential for growth is enormous.

Have you seen any recent Canadian installations of PV?

In May this year I visited a friend's acreage near Ottawa. He had just connected up his 10 kilowatt peak system to the Ontario Grid. A picture of the installation is shown in Figure 1.

The system is ground mounted, as there was insufficient room on the roof or walls of his house. The system cost will be paid back in about 6 years assuming there are no equipment problems. In Ontario, the owner of a small system will receive a price of 80.5 cents per kilowatt hour that is generated. Ontario is offering these incentives as a means of kick-starting a PV industry.

The modules are facing due south at a tilt angle of 37 degrees. Ottawa is located at 45 degrees latitude. The 37 degree tilt angle was based on the optimum fixed angle for year-round production according to the RETSCREEN computer program. In winter there will be times when the snow must be manually removed from the panels.

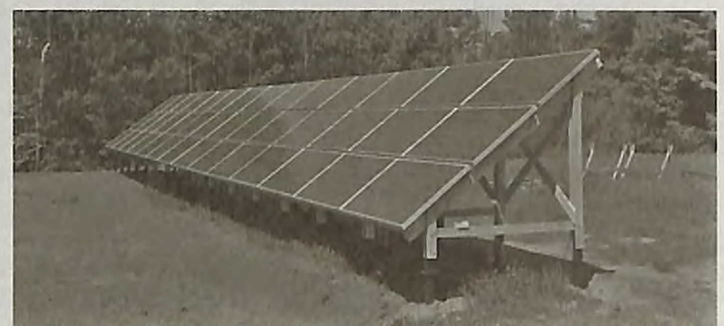

Figure 1. A 10 kilowatt peak photovoltaic installation near Ottawa

Have you seen any larger PV installations in Canada?

While in the Ottawa area, I visited the very large PV installation in Galetta, near Arnprior. This system, developed by EdF-EN and located on a 200 acre farmsite, has a peak production of 23,400 kilowatts.. This is apparently the largest PV installation in Canada. The panels use thin film technology. On these larger systems, the owner gets a reduced price of 42 cents per kilowatt hour on a 20-year contract. A photo of some of the panels is shown in Figure 2.

What implications do these projects have for house design?

1. Solar PV will, over the life of most houses in Canada, become one of the least costly electricity sources.
2. All new residences should be designed to be solar ready with a south-facing roof or wall surface that has unobstructed access to the sun for about 4 hours on either side of solar noon.
3. All new subdivisions should be laid out so that solar access is possible for all dwellings.
4. Solar rights legislation is needed to prevent neighbouring homeowners obstructing one's solar panels by growing trees or otherwise obstructing the access to the sun's rays. Japan has legislated solar rights.
5. Let's get on with it.

Figure 2. Part of the largest PV installation in Canada. The Arnprior Solar Installation. A web site, http://rimstar.org/renewnrg/sp_arnprior_solar_farm.htm has more information on the project.

Equilibrium House Update

Regrettably, the Alstonvale Net Zero House in Hudson, Quebec, one of CMHCs EQuilibrium demonstration homes suffered a setback, as fire destroyed the house May 25th. Source of the fire is under investigation.

NRC·CNRC

Use of Vents and Stacks for Natural Ventilation*

by Iain Macdonald, Boualem Ouazia and Liang (Grace) Zhou

The NRC Institute for Research in Construction has been investigating the use of hybrid ventilation systems for single-family residential buildings in terms of their potential for meeting code requirements, indoor air quality standards, and expectations for occupant satisfaction and energy efficiency. Hybrid ventilation combines both mechanical and natural ventilation.

The research is important because ventilation and air-conditioning can account for up to 50% of residential energy consumption, while having a direct impact on occupant health and comfort. Natural ventilation may result in too little or too much fresh air exchange, and may waste energy in heating or cooling a space. Mechanical ventilation is easily controlled and enables heat recovery and filtration but it consumes electrical energy and thereby promotes greenhouse gas emissions. Hybrid ventilation, combining the advantages of both natural and mechanical ventilation, may offer a way to reduce the energy used for building ventilation.

The NRC-IRC research is seeking to develop innovative hybrid ventilation strategies that will be suitable for houses, with or without good indoor air distribution provided by the forced-air heating system. The experiments will assess several hybrid strategies in terms of ventilation rates and distribution, energy consumption and thermal comfort, for a full range of weather conditions.

An important step in the process has been to understand the function and effectiveness of ventilation stacks and other passive ventilation devices (commonly used in Japan and Scandinavia).

Experiments

The experiments were conducted in the two-storey NRC-IRC Ventilation and Wall Research House facility in Ottawa. The house is fitted with three stacks (flues) and four basement vents equipped with motorized dampers (Figure 1) that permit the testing of several venting configurations.

For the experiments, the forced-air delivery duct system of the research house was configured to create a single ventilation zone and heating by means of an electric forced-air furnace or hydronic radiant system. The objective was to determine the change in overall air exchange rate in the house both with and without natural ventilation vents and stacks open.

Iain Macdonald, Boualem Ouazia and Grace Zhou are researchers in the Indoor Environment Program of the NRC Institute for Research in Construction.

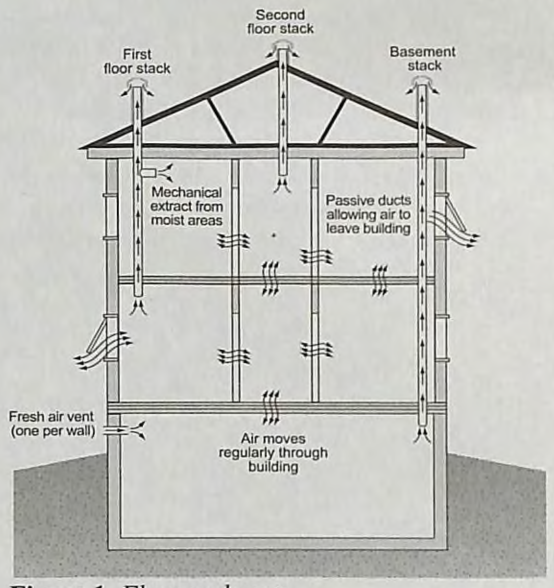

Figure 1. *Flues and vents*

Using tracer gas techniques, the study measured air change rate characteristics for 32 configurations for the forced-air cooling system (summer 2008), and 8 configurations for the hydronic radiant heating system and 16 configurations for the forced-air heating system running (winter 2009), with and without natural ventilation vents and stacks open.

The hydronic heating system was zoned on the first and second floors as shown on Figure 2 (i.e., temperature control was via thermostats in each room). To create a single air zone for the cases using hydronic heating, the furnace fan was left running, but all space conditioning was provided by the hydronic heating system.

Findings

During the summer, the stack/vent configurations were evaluated while the space was air-conditioned. Results are shown in Figure 3 and indicate that the greatest air change occurred with the combination of the second floor stack (outlet) and the basement vent (west) (inlet). Due to sheltering, wind direction had a greater effect on the vents than on the stacks, which explains why one vent might appear to perform better than another. Making the vents more reactive to wind direction will be part of the next stage of research (see Next Steps).

During the winter, the stack/vent combinations were evaluated with both the electric forced-air heating system and the hydronic radiant system with the forced-air fan running. For the hydronic heating system, all the vent/stack combinations had a minor influence on the air change rate of the house. For the forced-air heating system, the vents and stacks had a greater influence on the air change rate. The second floor stack had the most noticeable effect on the air change rate.

The winter testing confirmed the basic principle that stack effect increases with distance between a vent and a stack and with increasing temperature differential between the outside air and the conditioned interior air. This means that the second floor stack provided better ventilation than the other stacks.

The difference in the performance of the natural ventilation configurations for the hydronic and electric forced-air heating systems could not be explained by this initial round of experiments. This too will be the subject of further research (see Next Steps).

The results-to-date indicate that 1) there is indeed potential for using passive ventilation in combination with mechanical ventilation to reduce energy consumption without compromising indoor air quality, and 2) hybrid ventilation may offer an energy-efficient approach to meet ventilation requirements year round.

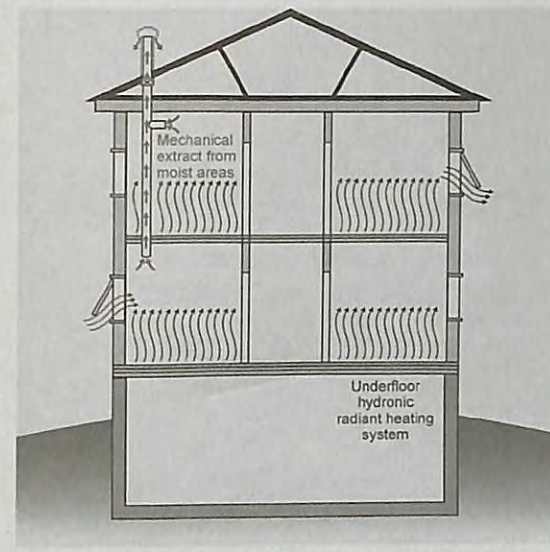

Figure 2. Hydronic radiant heating on the first and second floors

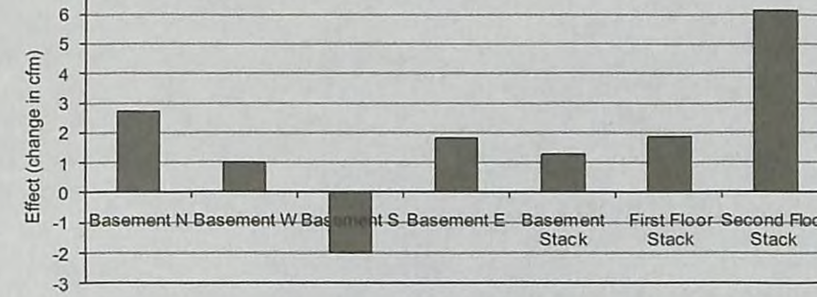

Figure 3. Air changes for stacks and vents

Next Steps

Future work will examine damper control and energy impacts of passive systems compared to standard HVAC designs. NRC-IRC will be running new experiments (full 16 runs, both heating systems) during the winter of 2010-11 to measure heating and ventilating energy consumption and to understand the differences in the vent and stack configurations on air change rate for the two types of heating. The next stage of research will also examine innovative control strategies such as: wind speed and direction-dependent actuated passive vents to achieve efficient hybrid ventilation regardless of wind direction and strength; and, using mechanical assistance to supplement natural ventilation when required.

For more information on ventilation, contact Iain Macdonald at 613-993-9676 or *iain.macdonald@nrc-cnrc.gc.ca*

For more information on radiant heating, contact Boualem Ouazia at 613-993-9613 or *boualem.ouazia@nrc-cnrc.gc.ca*

*A previous article in *Solplan Review* (September 2006) introduced the research described here.

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